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# PERFORMANCE ON A KEY PRESSING TASK AS A FUNCTION OF THE ANGULAR CORRESPONDENCE BETWEEN STIMULUS AND RESPONSE ELEMENTS

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## FOREWORD

This report was prepared by the University of Wisconsin under Contract No. AF 18(600)-54. The contract was initiated under a project identified by Research and Development Order 694-49, "Human Engineering Research on Fire Control and Missile Control Systems." The contract was administered by the Psychology Branch of the Aero Medical Laboratory, Directorate of Research, Wright Air Development Center with John W. Senders acting as Project Engineer.

ABSTRACT

This experiment was designed to investigate the effect of angular non-correspondence between indicators and controls upon performance of a task. Normally an engineer might be expected to arrange a series of control buttons in a row parallel to that of the corresponding indicators. Since this may not be possible it is of value to know how much performance suffers when there exists an angular non-correspondence between the row of indicators and the row of control buttons.

The indicators were eight red lights arranged in a row on a display panel. The subjects operated a finger keyboard of eight controls likewise arranged in a row. The row of stimulus lights could be placed in one of five angular orientations (of 0°, 45°, 90°, 135°, and 185° counterclockwise) relative to the fixed horizontal set of response keys. Five groups of 18 subjects were run; each group receiving only one of the angular orientation conditions. For the first part of the experiment half of the subjects of each group matched two-light patterns, the other half matched four-light patterns. For the second half of the experiment these conditions were reversed. A paced schedule was used in which a new pattern appeared .01 seconds after the preceding one was matched.

The results of the experiment showed that angular non-correspondence had a significant effect upon performance. The 0°, then the 90°, then the 135° and 180° stimulus light orientations led to successively poorer performance. The 45° orientation resulted in performance statistically indistinguishable from the 0° orientation among the five groups matching two-light patterns first and equal to the 90° orientation among the five groups matching four-light patterns first. Performance, however, was found to be much less impaired by angular non-correspondence than by spatial non-correspondence between indicators and controls as defined by Morin and Grant in an earlier experiment performed on the same apparatus. It was also shown that two-light patterns were matched significantly faster than four-light patterns with an overall advantage of 1.10 seconds per pattern on the average. Greater positive transfer effects were observed in transferring from four to two-light patterns than in transferring from two to four-light patterns.

PUBLICATION REVIEW

This report has been reviewed and is approved.

FOR THE COMMANDER:

Jack Bollerud

JACK BOLLERUD
Colonel, USAF (MC)
Chief, Aero Medical Laboratory
Directorate of Research

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## INTRODUCTION

This experiment was aimed at describing the function relating key-pressing performance and the angular orientation of a row of stimulus lights relative to the fixed horizontal arrangement of the keys. This is the second paper of a series dealing with some human engineering aspects of perceptual-motor behavior. More specifically, these studies relate to the problem of the placement of stimulus and response displays in situations such as confront fighter or bomber pilots and crewmen. In particular military and industrial applications, the space directly in front of an operator, where events are perceived and responded to most efficiently, may already be taken by S-R components of high priority. If more S-R components are to be added or existing ones are to be rearranged, the spatial orientations to which they are assigned may not be the most "compatible" (2, 3), and there arises the general problem of the present experiment: how much is performance degraded by employing S-R relations other than the most "compatible"?

Fitts and Seeger (3) have defined "compatibility" thus: "A task involves compatible S-R relations to the extent that the ensemble of stimulus and response combinations comprising the task results in a high rate of information transfer." They prefer to express the degree of compatibility in terms of information transmitted because of the utility of the information measure for their theoretical interpretation of perceptual-motor behavior, but agree that reaction time, number of errors, etc., are also admissible indices of the compatibility of S-R relations.

In the first of the present series of studies, Morin and Grant (4) studied pattern-matching performance as a function of different transpositional arrangements of the wiring connections between eight response keys and eight horizontal stimulus lights, where the Ss matched two-light stimulus patterns. Kendall's measure of rank correlation, $\tau$, was employed as an index of the correspondence between stimulus and response elements, and it was found that the compatibility of the two classes increased as the value of $\tau$ changed from $\pm$ 0.29 to $\pm$ 1.00.

In the present study, angular non-correspondence between stimulus and response elements was investigated. Normally an engineer might be expected to arrange response buttons in a row parallel to that of the corresponding stimulus elements, but other response buttons or the shape of the equipment, e.g., when buttons are placed on control knobs or columns, may require some angular difference between the stimulus and response rows. This experiment deals with angles from $0^{\circ}$ to $180^{\circ}$ between stimulus and response elements.

## METHOD

Apparatus. All Ss were run on the Multiple Serial Discrimeter, an apparatus designed and constructed at the University of Wisconsin Laboratory of Experimental Psychology (4, 5). It may be described in terms of five units:

(a) response display, (b) stimulus display, (c) stimulus programming unit, (d) control unit, and (e) operations recorder.

(a) The response display is pictured in Fig. 1. It consists of a row

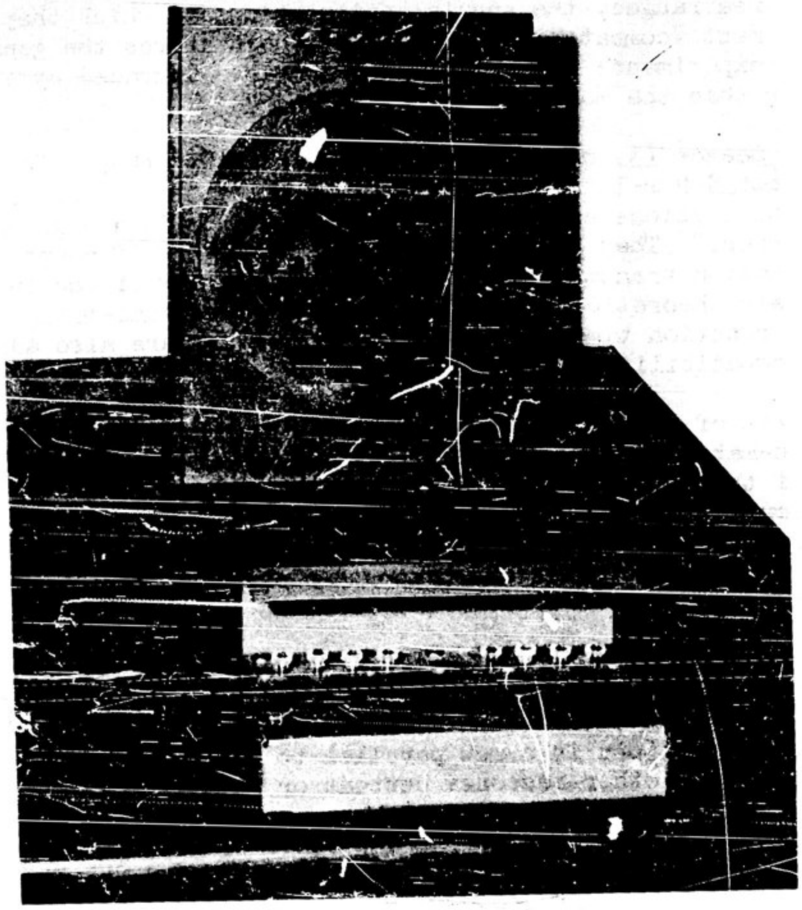

Fig. 1. The Stimulus Display and Response Display of the Multiple Serial Discrimeter.

of eight round lucite keys mounted on the top surface of a metal box (11" x 6.75" x 2"). The keys are one inch apart except for the middle pair, which are three inches apart. If a key is depressed 1/32 inch with 11 ounces of weight, a microswitch is closed. Each microswitch operates a relay in the scoring circuit and also controls one of the eight response feedback lights on the stimulus display. An adjustable metal shield on the response display prevents the S from seeing the keys or his fingers.

(b) The stimulus display is also pictured in Fig. 1. Eight red stimulus lights and eight green response feedback lights are mounted on the stimulus display in two groups, each group containing a row of four stimulus lights and a parallel row of four response lights. Each group is contained within one of two disks (five inches in diameter) that are symmetrically placed within a large 12 inch diameter disk. The two rows of lights within a small disk are one and one-half inches apart, while adjacent lights of the same color are one inch apart. The lights themselves are one-half inch in diameter.

When the two small disks are oriented so as to form a row of red lights parallel to a row of green lights, the two middle lights of either row are two and one-half inches apart. This orientation was constant throughout the present experiment, while the angle between the rows and the horizontal was varied in five steps of 45°. The stimulus display was 54 inches from the Ss' eyes, this distance varying about four inches in either direction as the Ss bent forward or leaned back. Five amber lights at the top of the stimulus display were not used in the present experiment.

(c) The stimulus programming unit determines which of the red lights will be lighted on a given trial. To each of the eight stimulus lights there corresponds a column on a paper tape. For a given row, if the "third" column has been perforated, then the "third" stimulus light will be turned on when that row advances to a position between electrical contacts. The different rows correspond to different trials, and the paper tape advances saccadically to a new row whenever a pattern has been matched.

(d) The control unit houses the circuitry necessary for stimulus presentation and scoring. Each of the 16 relays corresponds to one of eight stimulus or eight response lights. When, and only when, each of the eight response relays takes the same position as its corresponding stimulus relay an impulse is sent through all 16 relays to the stimulus programming unit. This causes the tape to advance and results in the rapid (.01 second) presentation of the next stimulus pattern. A pattern is matched when only those green lights corresponding to the activated red lights are all on.

(e) Response latencies and durations and the number of correct and incorrect responses corresponding to each successive stimulus pattern may be recorded by an Esterline Angus operations recorder. When this information is not desired, two Veedor-Root counters are used to obtain separate records of

the number of patterns presented and the number of patterns correctly matched. The total time per block of stimulus patterns is alternatively measured with a stop watch.

Subjects. Serving in the experiment were 90 male students selected from a pool of students who had responded to requests for part-time help as paid Ss at $0.85 per hour. They were randomly assigned to the 10 experimental groups under the restriction that each replication be completed before the next one was begun. No Ss were used who had been in previous MSD experiments.

Procedure and Design. Ss were run individually. Instructions were given via a tape recorder, and E sat at S's place during the instructions in order to illustrate certain statements. Questions were permitted at the end of the instructions.

The 10 experimental groups were formed by combining five angular separations of the row of stimulus lights from the horizontal (0°, 45°, 90°, 135°, and 180°, reading counter-clockwise) with two general types of patterns. For each angle, one group of nine Ss matched two-light patterns, then shifted to four-light patterns; whereas a second group first matched four-light patterns, then shifted to two-light patterns. The design is shown schematically in Fig. 2.

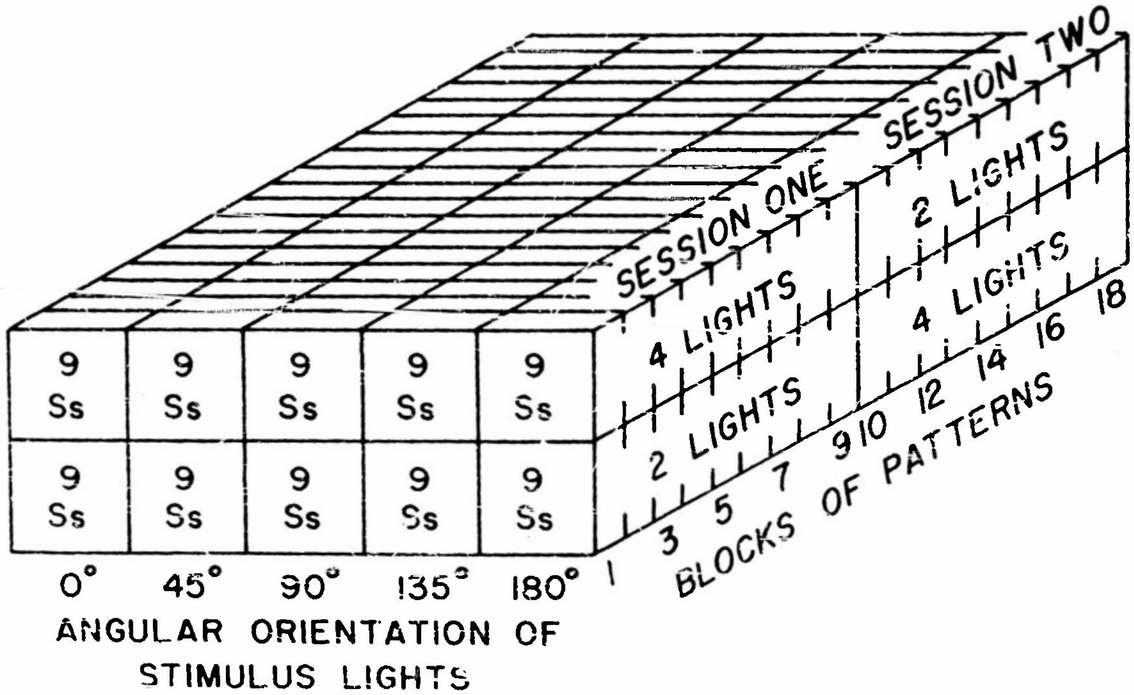


Fig. 2. The Experimental Design Used in the Present Experiment.

Each S had to match 450 stimulus patterns arranged in nine blocks of two-light and nine blocks of four-light patterns. The patterns within each set of nine blocks were randomly arranged under the restriction that the same pattern could not occur consecutively, and each S received the same order. After S had matched each block of patterns he was told how many seconds had been required.

## RESULTS

The data used were the average latency measures or mean number of seconds required to "match" the patterns of stimulus lights. The raw latency measures showed heterogeneity of variance which was corrected by the (rational) logarithmic transformation. The analyses are presented in terms of the transformed data; the figures, however, have been drawn on the basis of the original latency data.

The mean number of seconds required to match a pattern has been plotted as a function of the angular orientation of the stimulus lights in Fig. 3,

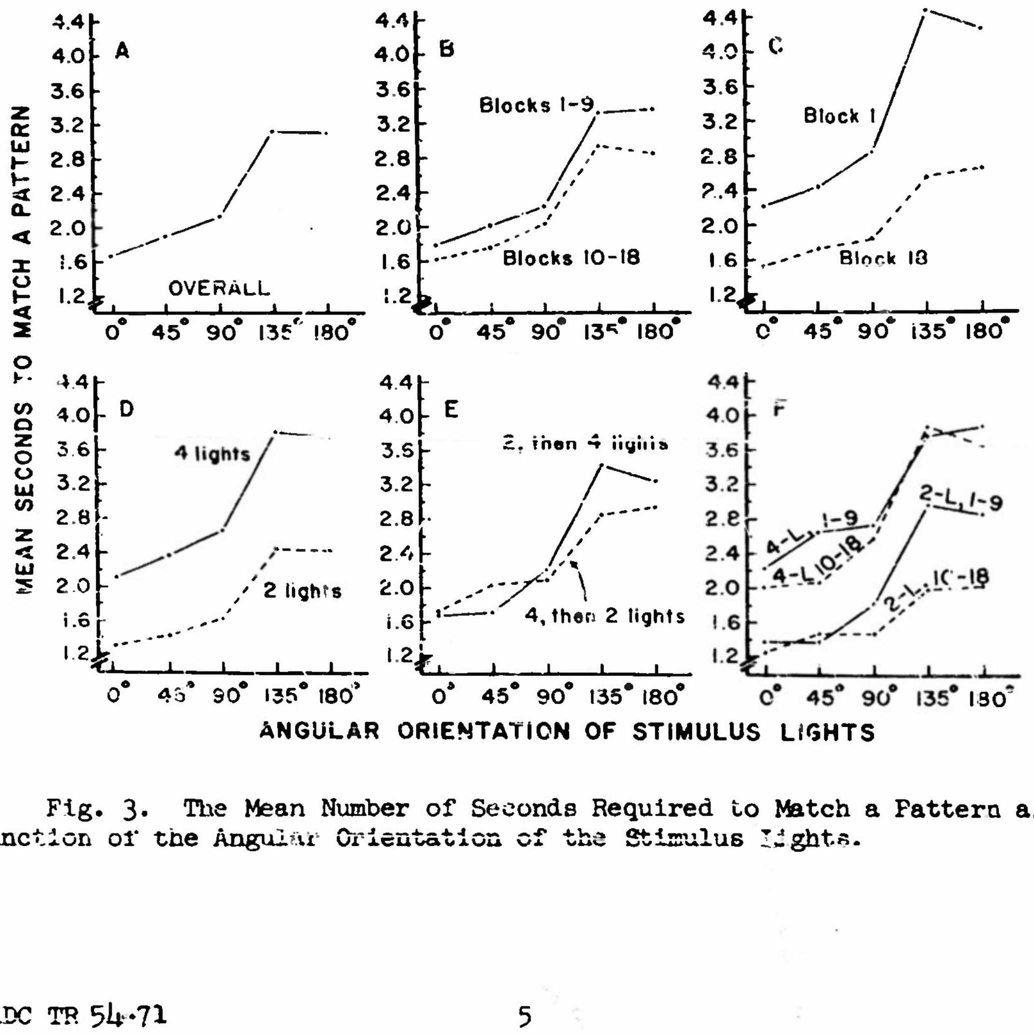


Fig. 3. The Mean Number of Seconds Required to Match a Pattern as a Function of the Angular Orientation of the Stimulus Lights.

where various sub-figures also show the effects of the practice and number-of-lights parameters. In Fig. 3A, the mean time to match a pattern is shown as it is affected by the angular orientation of the stimulus lights. As the angle increases from 0° to 135°, the latency increases from 1.71 to 3.14 seconds. There was no difference in pattern-matching time for the orientations of 135° and 180°. The significance of overall differences in the data of Fig. 3 were tested by means of analysis of variance and the summary of these tests is given in Table 1. Table 1 reveals that the difference between

TABLE I

Latin Square Analysis of the Data Obtained by Summing Across Blocks 1-9 and Blocks 10-18 for Each Subject.

| Source of Variance | S.S. | d.f. | M.S. | F ratios | p |
|---|---|---|---|---|---|
| Angles | 171.3836 | 4 | 42.8459 | 75.8*** | $< .001$ |
| Sessions | 11.3992 | 1 | 11.3992 | 20.2*** | $< .001$ |
| Lights | 151.1682 | 1 | 151.1682 | 267*** | $< .001$ |
| Subjects | 2.5106 | 1 | 2.5106 | 4.442* | $.025 < p < .05$ |
| Error | 97.2229 | 172 | 0.5652 | | |
| Total | 433.6847 | 179 | | | |

*Significant at or beyond the .05 confidence level.
***Significant at or beyond the .001 confidence level.

the angular orientations is significant at the .001 confidence level. The Latin Square analysis of Table 1 was performed on the scores that resulted after summing across the scores for blocks 1-9 and blocks 10-18 separately for each S.

In Figs. 3B and 3C, certain aspects of the practice variable are presented as parameters. In both figures, pattern-matching time shows much the same functional relation to stimulus-light orientation that was seen in Fig. 3A. The average performance level for the 0° condition was 1.62 seconds over blocks 10-18 (session 2) as contrasted to 1.80 seconds per pattern over blocks 1-9; and performance during the last nine blocks of patterns was, respectively, .26, .24, .43, and .53 seconds better than pattern-matching performance during the first nine blocks of patterns on the average for the other angular orientations. In Fig. 3C, first and eighteenth block pattern-matching times are plotted as a function of the stimulus light orientation to indicate the total overall learning and transfer effects. The amounts by which block 18 performance is faster than block 1 performance for the 0°, 45°, 90°, 135°, and 180° stimulus light orientations, respectively, are .69, .69, .99, 1.93, and 1.60 seconds per pattern on the average.

Again reference to Table 1 reveals that the difference between "sessions" (blocks 1-9 vs. blocks 10-18) is significant at the .001 confidence level, with an F of 20.2. The Latin Square analysis does not, of course, permit evaluation of a session by stimulus light orientation interaction. The significance between first-half and last-half performance, coupled with the observation that first-block and eighteenth-block performances were respectively poorest and best of the 18 blocks, made it obvious that performances were also significantly different between the first and eighteenth blocks.

Fig. 3D contrast pattern-matching performance on two-light patterns against that on four-light patterns for the five stimulus light orientations. Two-light patterns required 1.30, 1.43, 1.64, 2.45 and 2.44 seconds per pattern on the average for the five successive stimulus light orientations, corresponding values for the four-light patterns were 2.13, 2.37, 2.66, 3.82, and 3.77 seconds. Pattern-matching performance on two-light patterns thus averaged better than on four-light patterns by .83 to 1.37 seconds for the various stimulus light orientations.

The significance of performance differences resulting from two-light patterns and four-light patterns was tested and found to be significant at the .001 confidence level, as may be seen in Table 1. But because the variable, number of lights per pattern, was employed in the latin square manner, it is completely orthogonal to the variable, angular orientation of the stimulus lights, only during the first nine blocks of patterns. A modification of the Alexander Trend Analysis (1) was performed on this portion of the data in order to make a simple evaluation of the significance of interactions between stimulus light orientations, number of lights, and blocks of patterns. The results of this analysis are presented in Table 2. There, the significance of the Between Group $\text{Means}_{A \times L}$ term (line F), when tested against the error estimate Individual Deviations From Estimation (line N), means that pattern-matching performance has a somewhat different functional relation to the stimulus light orientation variable when two-light patterns are employed than when four-light patterns are employed. This may be most readily seen in Fig. 3F, by referring to the curves labelled "2-L: 1-9", and "4-L: 1-9". The most apparent difference is that performances are nearly equal for the four-light pattern groups having 45° and 90° stimulus light orientations, whereas it is the performances of the 0° and 45° stimulus light orientation groups that are nearly equal for the two-light pattern groups. Another difference is that 180° performance is poorer than 135° performance for the four-light pattern groups during the first session, but the reverse is the case with the two-light pattern groups during the first session. Other aspects of Table 2 will be referred to later.

In Fig. 3E, the mean number of seconds required to match a pattern has been plotted as a function of stimulus light orientation for the five groups receiving nine blocks of two-light patterns followed by nine blocks of four-light patterns, and also for the five groups receiving four-light patterns followed by two-light patterns. The groups having 0° and 45° stimulus light orientations performed faster if they had started out on two-light patterns rather than on four-light patterns. But the groups having 90°, 135°, and 180° stimulus light orientations performed faster if they had started out on four-light patterns rather than on two-light patterns. The data of Fig. 3E (after)

TABLE II

A Modification of Alexander's Trend Analysis Applied to the Data of Blocks 1-9.

| Source of Variance | S. S. | d.f. | M. S. | F ratios |
|---|---|---|---|---|
| Group Deviations From Estimation | | | | |
| A. Angles | .0352 | 28 | .0013 | A/N ---- |
| B. Lights | .0376 | 7 | .0054 | B/N 3.18** |
| C. Angles x Lights | .0585 | 28 | .0021 | C/N 1.24 |
| Total | .1312 | 63 | | |
| Between Group Means | | | | |
| D. Angles | 11.0480 | 4 | 2.7620 | D/L 44.9*** |
| E. Lights | 6.3731 | 1 | 6.3731 | E/L 104*** |
| F. Angles x Lights | 0.8485 | 4 | .2121 | F/L 3.45* |
| Total | 18.2696 | 9 | | |
| Between Group Slopes | | | | |
| G. Angles | .1568 | 4 | .0392 | G/M 9.56*** |
| H. Lights | .0142 | 1 | .0142 | H/M 3.46* |
| I. Angles x Lights | .0135 | 4 | .0034 | I/M ---- |
| Total | .1845 | 9 | | |
| J. Overall Deviations From Linearity | .7136 | 7 | .1019 | J/N 59.9*** |
| K. Overall Slope | 3.5875 | 1 | 3.5875 | K/N 210*** |
| L. Between Individual Means | 4.9169 | 80 | .0615 | L/N 36.2*** |
| M. Between Individual Slopes | .3284 | 80 | .0041 | M/N 2.41*** |
| N. Individual Deviations From Estimation | .9550 | 560 | .0017 | |
| | | 809 | | |

*Significant at or beyond the .05 confidence level.
** Significant at or beyond the .01 confidence level.
*** Significant at or beyond the .001 confidence level.

transformation) were tested for significance by analysis of variance, and the results are presented in Table 3. The significance, in Table 3, of the "Angles"

TABLE III

Analysis of Variance Applied to the Data (after transformation) of Fig. 3E.

| Source of Variance | S.S. | d.f. | M.S. | F ratios | |
|---|---|---|---|---|---|
| Angles | 342.7672 | 4 | 8.5691 | 4.455** | .001<p<.005 |
| Order (2-4 vs. 4-2) | 5.0215 | 1 | 5.0215 | 2.611 | .10< p<.20 |
| Angles x Order | 23.8433 | 4 | 5.9608 | 3.099* | .01< p<.025 |
| Error | 153.8817 | 80 | 1.9235 | | |
| Total | 525.5137 | 89 | | | |

*Significant at or beyond the .05 confidence level.
**Significant at or beyond the .01 confidence level.

x "Order" interaction means that the relationship of pattern-matching time to stimulus light orientation further depends upon the order in which the nine blocks of two-light or four-light patterns are encountered. When the effects of stimulus light orientation are isolated through analysis from the effects of "order", i.e., when one deals only with the "order" variable and sums across the other variable to remove its differential effect on performance, then the order in which the two-light and four-light patterns occur does not have a significantly different effect on pattern-matching time. The actual values were 2.34 and 2.46 seconds per pattern on the average for the group receiving first four-light, then two-light patterns, and the group receiving first two-light and then four-light patterns, respectively. The difference between stimulus light orientations, as in all the analyses performed, was again significant at or beyond the .005 confidence level.

In Fig. 3F, there has also been plotted the pattern-matching performance of the four-light and two-light groups during the last session (blocks 10-18) as a function of the stimulus light orientation. The groups having two-light patterns during the last session averaged 1.63 seconds per pattern, those having four-light patterns during the last session averaged 2.94 seconds per pattern. The relation between pattern-matching time and stimulus light orientation seems to depend upon the number of lights per pattern during the second session as well as during the first session. In order to test the significance of this apparent interaction between stimulus light orientation and number of lights per pattern during the second session, an analysis of variance was performed on this part of the data and the results are presented in Table 4. Under the null hypothesis an interactive difference between stimulus light orientation and number of lights per pattern as large as that obtained would occur by chance between five and ten times out of a hundred - too often to

TABLE IV

Analysis of Variance Applied to the Data Obtained by Summing Across Blocks 10-18.

| Source of Variance | S.S. | d.f. | M.S. | F ratios | p |
|---|---|---|---|---|---|
| Angles | 72.9929 | 4 | 18.2482 | 36.75*** | .001 |
| Lights | 96.3214 | 1 | 96.3214 | 193.9 *** | .001 |
| Angles x Lights | 4.5675 | 4 | 1.1418 | 2.299 | .05 p .10 |
| Error | 39.7247 | 80 | 0.4965 | | |
| | 213.6066 | 89 | | | |

*** Significant at or beyond the .001 confidence level.

accept this observed interaction as being statistically significant when one is employing the .05 confidence level (a la Neyman-Pearson). The observed difference in performance as a function of number of lights per pattern during the second session was statistically significant with an F of 194.

The analysis of Table 4 again revealed significant differences in pattern-matching performance due to the five different stimulus light orientations. To see if any further conclusions could be drawn about the relationship of pattern-matching performance to stimulus light orientation, the gap-testing method proposed by Tukey (6) was employed to compare the five mean pattern-matching times within each of the four curves of Fig. 3F. The results are collected in Table 5.

TABLE V

The Results of Applying Tukey's Method of Comparing Individual Means to the Four Curves of Fig. 3F.

| Parameter | Performance Level Best | Middle | Poorest |
|---|---|---|---|
| Two-Light Patterns, Blocks 1-9 | $0^\circ$, $45^\circ$ | $90^\circ$ | $135^\circ$, $180^\circ$ |
| Four-Light Patterns, Blocks 10-18 | $0^\circ$, $45^\circ$ | $90^\circ$ | $135^\circ$, $180^\circ$ |
| Four-Light Patterns, Blocks 1-9 | $0^\circ$ | $45^\circ$, $90^\circ$ | $135^\circ$, $180^\circ$ |
| Two-Light Patterns, Blocks 10-18 | $0^\circ$ | $45^\circ$, $90^\circ$ | $135^\circ$, $180^\circ$ |

On the basis of Tukey's test the five stimulus light orientations lead to three reliably different levels of performance. In all cases, the $0^\circ$ orientation leads to the best performance, the $90^\circ$ procedure is in the middle, and the $135^\circ$ and $180^\circ$ orientations lead to the poorest performance. An exception to

this consistency is the performance of the $45^{\circ}$ stimulus orientation procedure. Of the five groups matching two-light patterns before matching four-light patterns, the $45^{\circ}$ orientation leads to performance that is not distinguishable from the performance of the $0^{\circ}$ stimulus orientation group. On the other hand, of the five groups matching four-light patterns before matching two-light patterns, the $45^{\circ}$ stimulus orientation leads to performance that is not distinguishable from the performance of the $90^{\circ}$ stimulus orientation group.

Figs. 4 and 5 have been drawn with three dimensions in order to show the

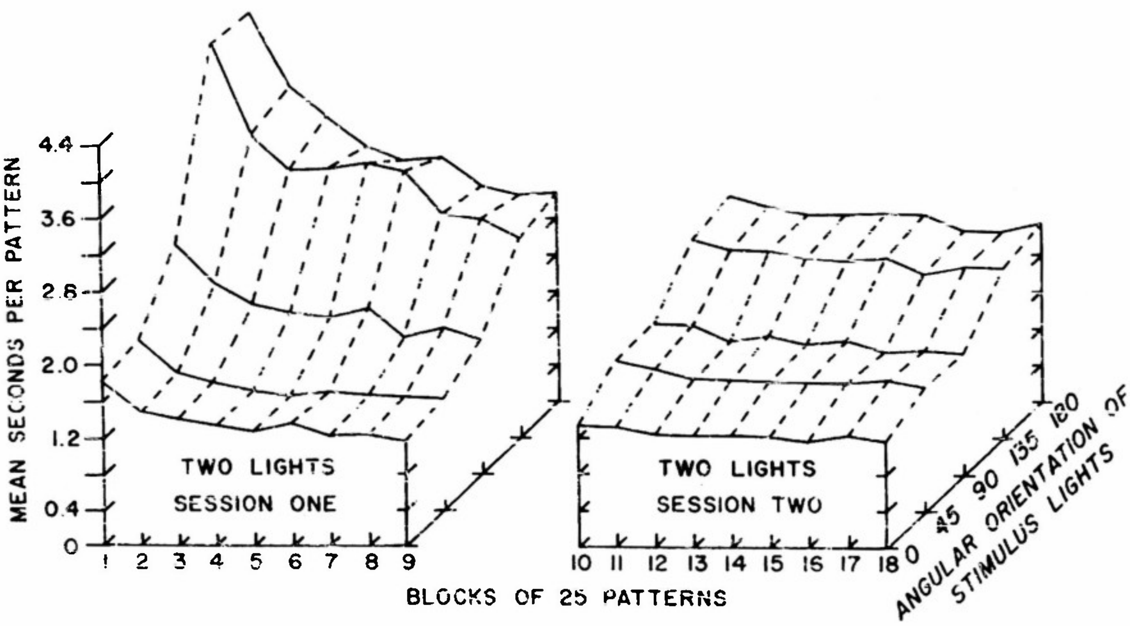


Fig. 4. The Mean Time Required to Match Two-Light Patterns Has Been Plotted as a Function of Blocks of Patterns and the Angular Orientation of the Stimulus Lights.

joint operation of the practice and stimulus light orientation variables. More readily than Fig. 3C, these figures show the considerable improvement in per-

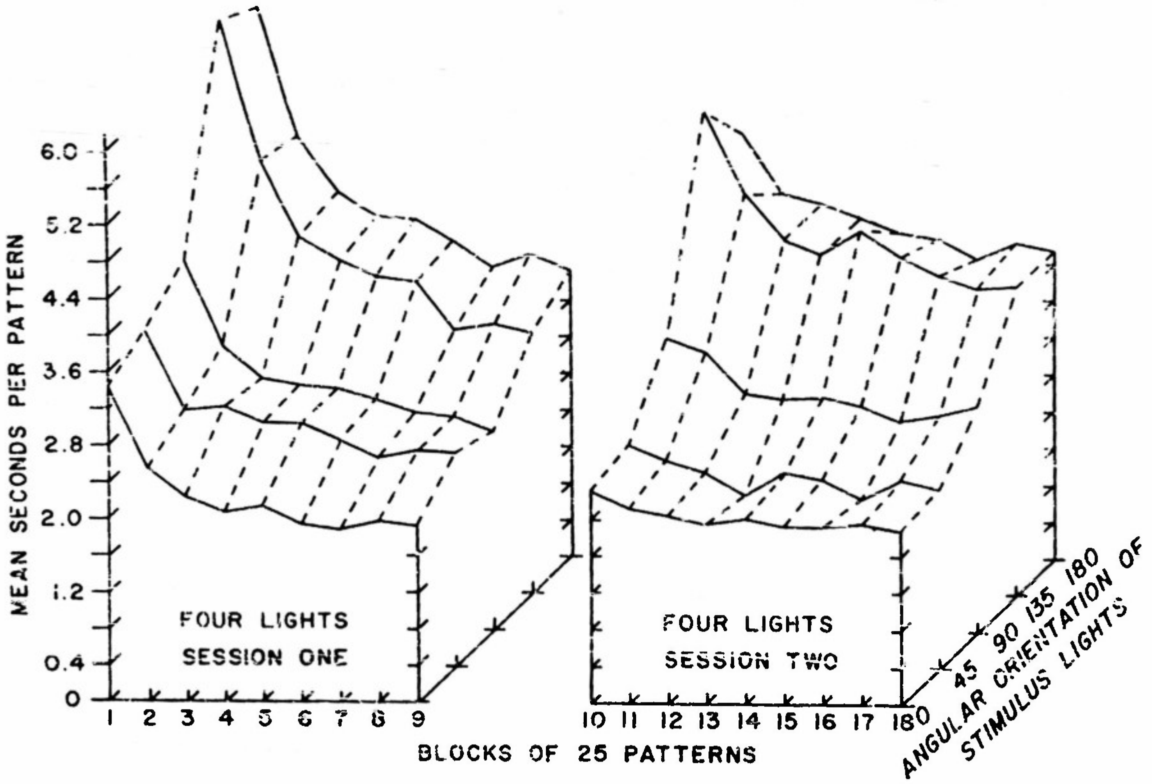


Fig. 5. The Mean Time Required to Match Four-Light Patterns Has Been Plotted as a Function of Blocks of Patterns and the Angular Orientation of the Stimulus Lights.

formance due to practice. Within each of the four treatment combinations (of sessions and number of lights per pattern), the learning trends for the different stimulus light orientations seem to be uniform from block to block. A statistical check on the learning trends of both the stimulus light orientation effect and the number-of-lights-per-pattern effect was made on the data of the first session only, and the results are presented in the trend analysis of Table 2. The non-significance of the source of variance, "Group Deviations From $\text{Estimation}_{\text{angles}}$" (line A of Table 2) means that the stimulus light orientation effect does not significantly change in form during the first nine blocks of practice. However, the effect of the number of lights per pattern does change significantly during the first nine blocks of patterns, as indicated by the significance of the "Group Deviations From $\text{Estimation}_{\text{lights}}$" (line B of

Table 2). This probably results from the more extensive and perhaps more rapid improvement of the groups matching four-light patterns in relation to the improvement of the groups matching two-light patterns.

The data shown in Figs. 4 and 5 also show the superiority of transferring from matching four-light patterns to matching two-light patterns as compared with transferring from two-light to four-light patterns. In Fig. 4, the data of the second session were obtained from Ss who had matched four-light patterns during the first session and these data appear as virtual continuations of the first session data. In Fig. 5, however, the data of the second session show little positive transfer from matching two-light patterns and may show some interference effects.

## DISCUSSION

The present experiment has assessed the compatibility of five angular orientations of a set of stimulus lights with a set of fixed horizontal keys. While it was observed in general that the greater the angular displacement from zero, the less compatible were the stimulus and response displays, the five angular orientations could be associated with only three different levels of performance on the basis of a statistical test. The 0°, then the 90°, then the combined 135° and 180° stimulus light orientations led to the best, middle, and poorest levels of performance, respectively. The performance of the 45° orientation was like that of the 0° orientation among the five groups matching two-light patterns first and like that of the 90° orientation among the five groups matching four-light patterns first.

The meaning of this inconsistency or interaction might be that it was easier to generalize from the usual or most familiar types of correspondence (presumably equivalent to the 0° orientation) to the 45° situation when only two lights had to be matched than when four lights had to be matched.

A comparison of two-light pattern-matching performance in the present experiment can be made with two-light matching performance in the experiment reported by Morin and Grant (4). In both experiments, nine Ss in each of five stimulus light orientation groups or in nine levels of spatial correspondence between S-R elements (as indicated by the rank correlation coefficient, $r$ ) practiced on nine blocks of 25 two-light patterns per block. The data have been plotted in Fig. 6. It is evident that altering the spatial correspondence between S-R elements, as Morin and Grant have done, makes these elements much less compatible than changing the stimulus light orientation in the mode of the present experiment. Interestingly, the stimulus display takes the same position for a $r$ of + 1.00 as for a 0° stimulus light orientation; the same identity holds for a $r$ of − 1.00 and a 180° stimulus light orientation, with the exception that the red lights are above the green for the $r$ value and be-

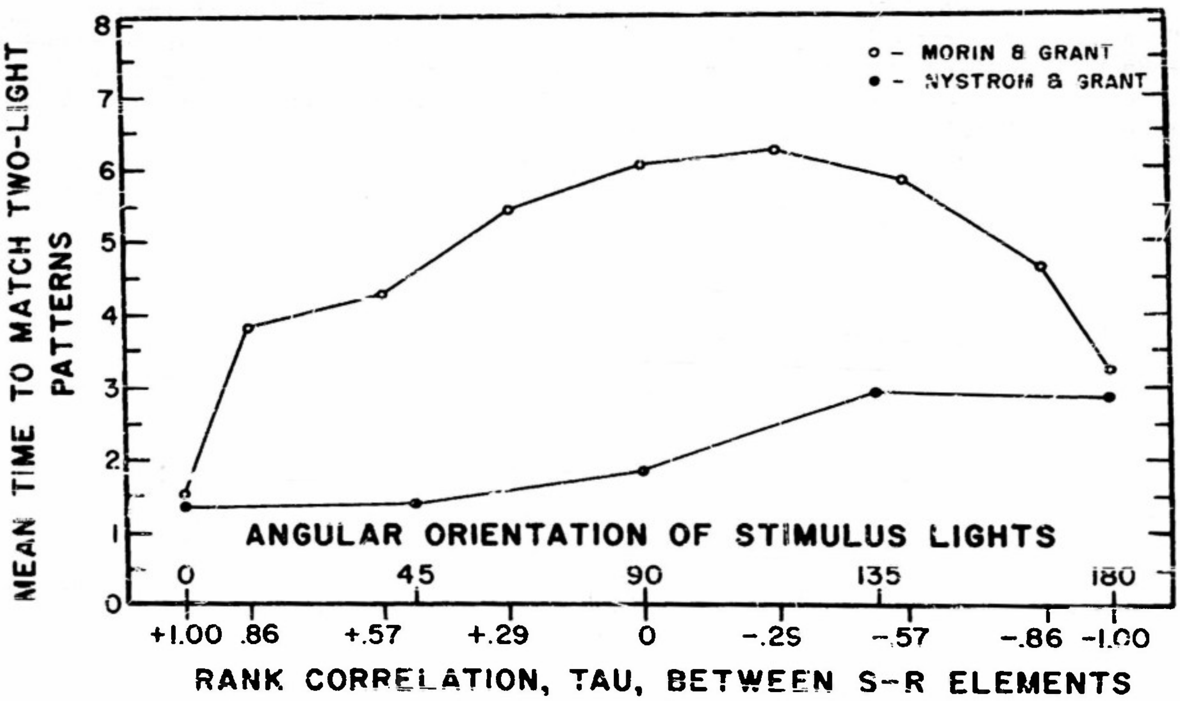


Fig. 6. A Comparison of the Mean Time Required to Match Two-Light Patterns in the Present Experiment (i.e., as a Function of the Angular Orientation of the Stimulus Lights) with That in the Morin and Grant Experiment (i.e., as a Function of the Rank Correlation, τ, Between Stimulus and Response Elements).

low the green lights for the orientation value. The differences in average latency are .14 and .40 seconds, both favoring the groups of the present experiment, whereas the pattern-matching times would be expected to be the same in the two situations. Whether or not these differences would turn out to be statistically significant, the present experiment employed a difference in procedure which to some unknown degree affects these comparisons. That is, Ss were given knowledge of their time scores after each block of patterns in the present experiment, but this was not done in the Morin and Grant experiment. In any case, the differences at these two check points are so small relative to other differences that they are of minor concern.

The findings of the present study, therefore, suggest that angular non-correspondences up to 45° between stimulus and response elements may not seriously degrade key-pressing behavior. Also, considering the earlier findings of Morin and Grant (4), it appears that human Ss are better able to tolerate and correct for angular non-correspondences than transpositional or permutational non-correspondences. The degradation due to lack of angular stimulus-response correspondence was initially greater for complicated (four-light) performances, but a short training session eliminated degree of complication of responses as a factor in the degradation of performance due to lack of angular correspondence of stimulus-response elements.

## SUMMARY

Five groups of 18 Ss per group performed a key-pressing task which differed between groups in that the stimulus light display took angular orientation relative to a fixed horizontal set of keys of 0°, 45°, 90°, 135°, and 180° counter-clockwise. Orthogonally to this independent variable, half the Ss matched two-light patterns, the other half matched four-light patterns. After nine blocks of 25 two or four-light matches, each S was shifed to four or two-light patterns, respectively.

1. There was a significant difference in the effects on performance due to the stimulus light orientation variable. The 0°, then the 90°, then the combined 135° and 180° orientations led to successively poorer performance. The 45° orientation resulted in performance equal to that of the 0° orientation among the five groups matching two-light patterns first, equal to that of the 90° orientation among the five groups matching four-light patterns first.

2. Two-light patterns were matched significantly faster than four-light patterns, with an overall advantage of 1.10 seconds per pattern on the average.

3. The number of lights per pattern interacted with the stimulus light orientation effect on performance during the first nine blocks of patterns, in that a somewhat different relationship existed between pattern-matching time and stimulus light orientation depending on whether two-light or four-light patterns were employed.

4. Performance was found to be much less impaired by employing changes in angular stimulus light orientation than when the spatial correspondence between S-R elements was altered as in the study by Morin and Grant (4) performed on the same experimental apparatus.

5. Greater positive transfer effects were apparent in transferring from four-light to two-light patterns than in transferring from two-light to four-light patterns.

6. Although initially the degrading effect of angular orientation was greater for the four-light patterns than for the two-light patterns, after training the angular effect was equal for the two performances.

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